VEGETATION SPECIES COMPOSITION AND CANOPY ARCHITECTURE INFORMATION EXPRESSED IN LEAF WATER ABSORPTION MEASURED IN THE 1000 nm AND 2200 nm SPECTRAL REGION BY AN IMAGING SPECTROMETER

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1. INTRODUCTION

Plant species composition and plant architectural attributes are critical parameters required for the measuring, monitoring, and modeling of terrestrial ecosystems. Remote sensing is commonly cited as an important tool for deriving vegetation properties at an appropriate scale for ecosystem studies, ranging from local to regional and even synoptic scales (e.g., Wessman, 1992). Classical approaches rely on vegetation indices such as the Normalized Difference Vegetation Index (NDVI) to estimate biophysical parameters such as leaf area index or intercepted photosynthetically active radiation (IPAR). Another approach is to apply a variety of classification schemes to map vegetation and thus extrapolate fine-scale information about specific sites to larger areas of similar composition. Imaging spectrometry provides additional information that is not obtainable through broad-band sensors and that may provide improved inputs both to direct biophysical estimates as well as classification schemes. Some of this capability has been demonstrated through improved discrimination of vegetation (e.g., Roberts et al., 1992, 1993a), estimates of canopy biochemistry (e.g., Wessman et al., 1988) and liquid water estimates from vegetation (Green et al., 1991, 1993, and Roberts et al., 1993b, 1994). In this paper we investigate further the potential of leaf water absorption estimated from Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data as a means for discriminating vegetation types and deriving canopy architectural information. We expand our analysis to incorporate liquid water estimates from two spectral regions, the 1000-nm region and the 2200-nm region.

The study was conducted in the vicinity of Jasper Ridge, California, which is located on the San Francisco peninsula to the west of the Stanford University campus. AVIRIS data were acquired over Jasper Ridge, CA, on June 2, 1992, at 19:31 UTC (Figure 1). Spectra from three sites in this image were analyzed. These data are from an area of healthy grass, oak woodland, and redwood forest, respectively. For these analyses, the AVIRIS-measured upwelling radiance spectra for the entire Jasper Ridge scene were transformed to apparent surface reflectance using a radiative transfer code-based inversion algorithm (Green, 1990; Green et al., 1993).

2. LEAF LIQUID WATER DETERMINATIONS

The absorption of water expressed in the reflectance of leaves in the AVIRIS spectra was modeled as the equivalent path transmittance through liquid water. For this model, the absorption coefficient for water was used to fit the expressed absorption of water and a linearly varying spectral albedo parameter was used to account for the spectrum brightness. Liquid water was estimated from two spectral regions, the 1000-nm region, where absorption is low, and the 2200-nm region, where leaf water absorption ranges from moderate to high.

A nonlinear least squares algorithm was developed to fit the modeled spectrum to the measured spectrum, minimizing the residual over a specified spectral range. Results are first presented for the 1000-nm region. For the healthy grass, an equivalent path of 1.83 mm was determined for liquid water as the best fit between the AVIRIS spectrum and the model (Figure 2). This path results from a combination of transmittance and scattering from single leaves as well as from multiple scattering within the grass canopy. In comparison, fitted leaf water for evergreen oak woodland was 2.16 mm, and for redwood forest, it was 3.48 mm (Figure 2). Large differences in equivalent path transmittance of liquid water expressed in the spectra were shown for these three species types. These differences result from the species' leaf thickness as well as from canopy architecture. The trend shown is for the equivalent path transmittance of liquid water to increase as the species type changes from thin to thick leaves, and as the canopy changes from shallow to deep.

The leaf water equivalent path transmittance model has been inverted for the entire AVIRIS scene using a 1000-nm spectral region (Figure 3). This image shows a number of distinct contiguous plant communities mapped in terms of the expressed leaf water. The equivalent path transmittance model was applied to these same spectra in the 2200-nm spectral region. Resulting estimates of leaf water path were considerably lower in the 2200-nm region when compared to the 1000-nm region, producing estimates of 0.37, 0.81, and 1.03 mm for the healthy grass, evergreen oak woodland, and redwood forest, respectively (Figure 4). In this spectral region, strong absorption results in reduced transmittance and scattering of light at the individual leaf and canopy scales; this results in reduced overall brightness and reduced expression of the liquid water absorption. Contrast in the 2200-nm region may be further reduced by spectral reflection off leaf surfaces which, in regions of low spectral reflectance, may constitute a majority of the reflected signal. The difference in total expressed water between species in conjunction with the contrast in expressed water between spectral regions provides information on both the plant species composition and plant architectural attributes.

3. CONCLUSION

Expressed leaf water derived from AVIRIS spectra using an equivalent path transmittance model was compared for three communities consisting of markedly different plant species with divergent plant architectures. A difference in expressed water derived from the 1000-nm spectral region was shown for the healthy grass, evergreen oak woodland, and redwood forest sites in AVIRIS data from Jasper Ridge. The expressed leaf water was determined for the full AVIRIS image, showing the differentiation of plant communities based on this parameter. Furthermore, there were differences between the expressed liquid water in the 1000-nm and 2200-nm spectral region for these communities. These results are consistent with differences in plant leaf and canopy architecture properties between these vegetation types. Derivation of plant species type and canopy architectural information through imaging spectrometer measurements provides a new approach for determining these vegetation parameters remotely at a range of scales. Future work will incorporate leaf and canopy optical models to more quantitatively relate the expressed leaf water in different portions of the spectrum to the physical properties of the vegetation.

4. ACKNOWLEDGMENTS

The research described in this paper was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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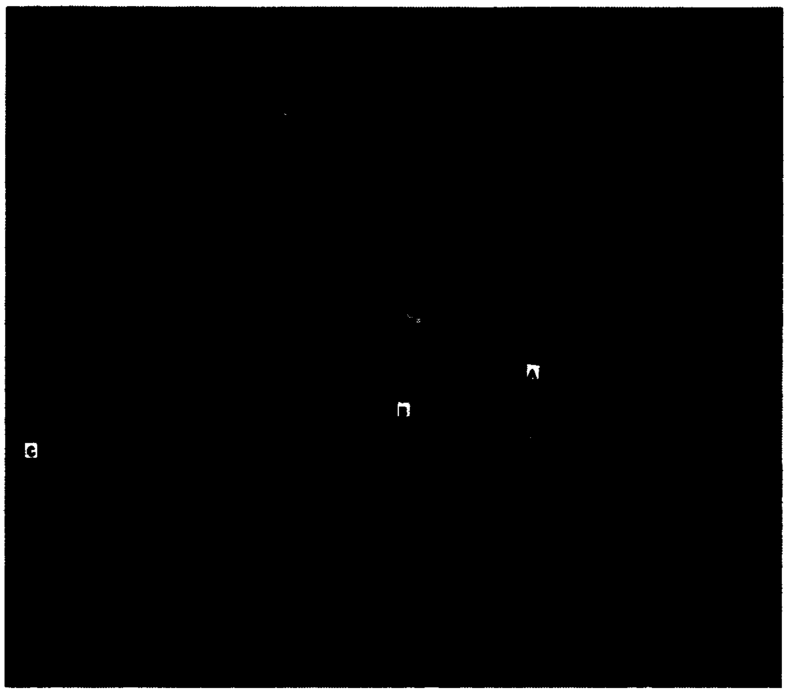

Figure 1. AVIRIS image of Jasper Ridge, CA, acquired on June 2, 1992 at 19:31 UTC. Sites A, B, and C show the locations of the healthy grass, oak woodland, and redwood forest plant communities, respectively (see AVIRIS Workshop Slide 5).

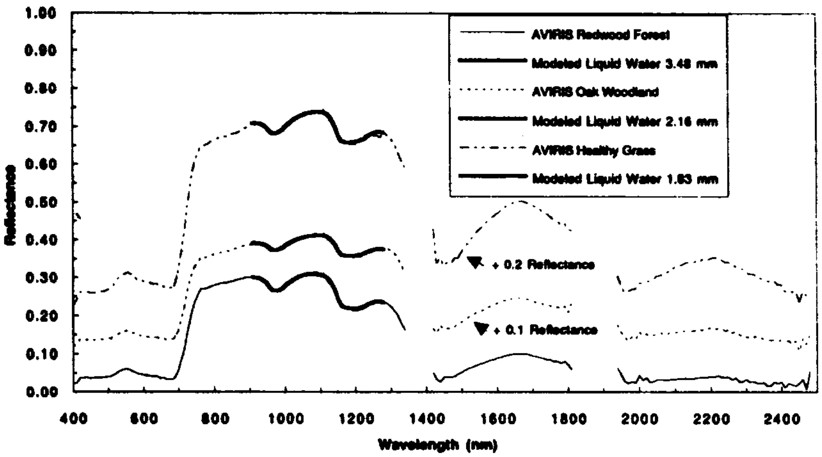

Figure 2. Equivalent path transmittance leaf water for healthy grass, oak woodland, and redwood forest in the 1000-nm spectral region.

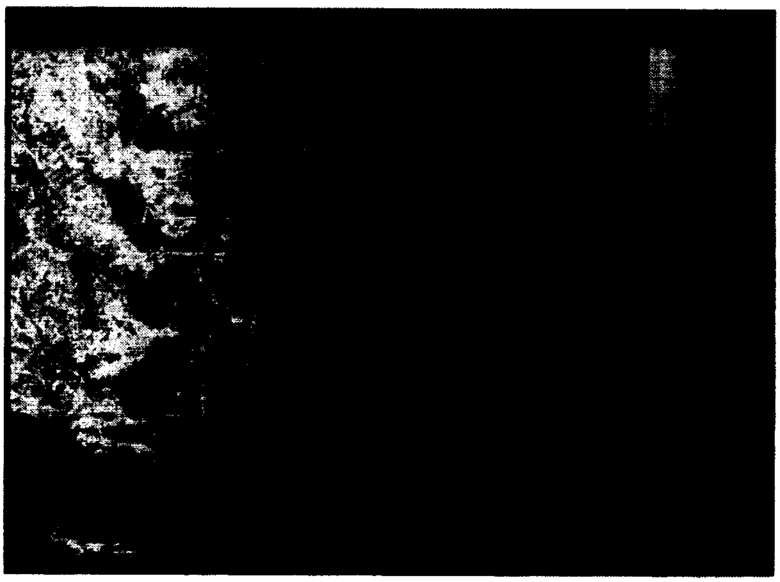

Figure 3. Image of liquid water equivalent path transmittance for the Jasper Ridge AVIRIS scene in microns (see AVIRIS Workshop Slide 5).

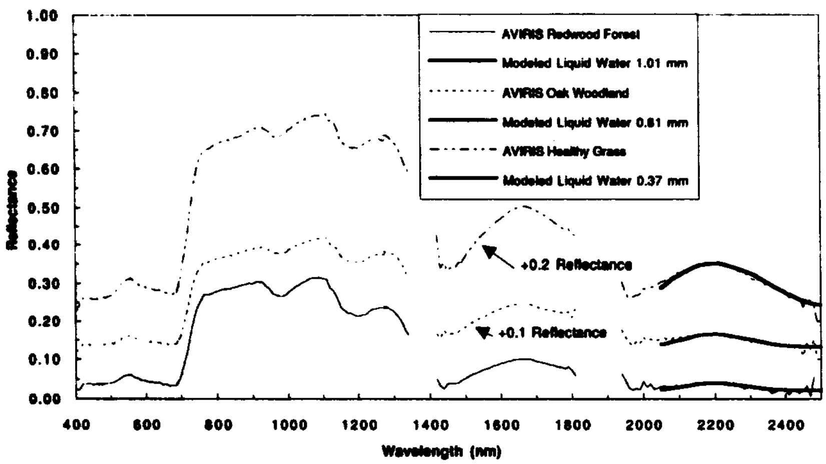

Figure 4. Expressed leaf water for healthy grass, oak woodland, and redwood forest at 2200 nm.